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Isotopic geochemistry utilization in the determination of the origin recharge of the water springs of the Algerian upper plains

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Abstract

Chemical and isotopic properties of water springs have been studied in Aures massif, which is located South of Algerian upper plains, city of Khenchela, Northeast of Algeria. The physico - chemical and isotopic characteristics of water springs samples have been studied in order to assess the origin of groundwater and determine the factors involved in its geochemical composition. The water springs of Algerian upper plains, initially weakly mineralized, can become salty by interaction with surrounding basin rocks and successive evaporation. The salt concentrations can increase up to the precipitation of evaporites.The use of chemical and isotopic tools has shown that Water springs are of bicarbonate-calcium facies. The origin of waters mineralization is linked to water-rock interactions, by mineral dissolution and cations exchange, and shows that the waters springs are undersaturated with respect to calcite, dolomite, aragonite, gypsum, anhydrite and halite. The isotopic tool has demonstrated that the aquifer recharge is ensured by meteoric mediterranean waters, with altitudinal influence.

1. Introduction

Water springs represent an important source of drinking water in many countries around the world where the importance of water quality in human health has recently attracted a great deal of interest [1-3]. In the developing world, 80 % of all diseases are directly related to poor drinking water and unsanitary conditions [4,5]. These water springs are also used for irrigation and for producing electricity (hydropower plants). For all these reasons, water resources must be managed in a sustainable way. Since the significance of water springs as important water resources and valuable ecosystems is growing worldwide, these hydrological systems are receiving rapidly increasing attention from the scientific, engineering, and regulatory communities. Literature shown that groundwater plays a dominant role in this part of Algeria received various studies [6-10]. Because of the lack of permanent surface water reservoirs owing to the hard climatic conditions, it constitutes the most widely available source of fresh water. In this region, groundwater is used for domestic and agricultural purposes. The present article aims to identify the origin of the water springs recharge of the Algerian upper plains, and to distinguish the salinity origin of the groundwater masses.

2. Experimental details

2.1. Location and climate

The study area is located in the Algerian upper plains, between Tell Atlas to the North and Saharan Atlas to the South, between 35◦15' and 35◦45'N of latitude and between 6 and 7° of longitudes (Figure 1). The climate of the study area is semi-arid, the average annual rainfall is 470 mm and the average annual temperature is around 16 ° C.

The study area is a hydrogeological entity of the steppe upper plains, surrounded by landforms having the geological aspects of the Algerian Atlas, formed by a very pleated field, fractured and karstified, having a Cretaceous frame and a very thick tertiary recoverment composed of gypseous red clay and sandstone, and leans directly and discordantly on the lower Cretaceous. The marly cretaceous, marlo-calcareous and sole compact limestone of gypseous and salifere trias recover the powerful series of Miocene sandstone that have a poor hydrogeological interest. The center of the plain is a collapse basin filled by detrital deposits, where conglomerates, gravels, fine sand and red clay have been deposited alternatively in an aquifer multilayer system of Quaternary age. The South and South-West borders of the basin are formed by the mountains of Aures (Figure 1). These latter are constituted of the karstic formations, that are the bottom of a deep aquifer having a limited extension toward the plain center and that sink slightly to the North, which would favour the flow and drainage of these waters of karstic origin toward the basin of Chemora (Figure 2) [11, 12]. Hydrogeologically, the region has two types of aquifers: the multilayer aquifers of the sedimentary basin constituted of the aquifers of Plio-Quaternary, and the aquifers of the carbonate fissured formations of Cretaceous.

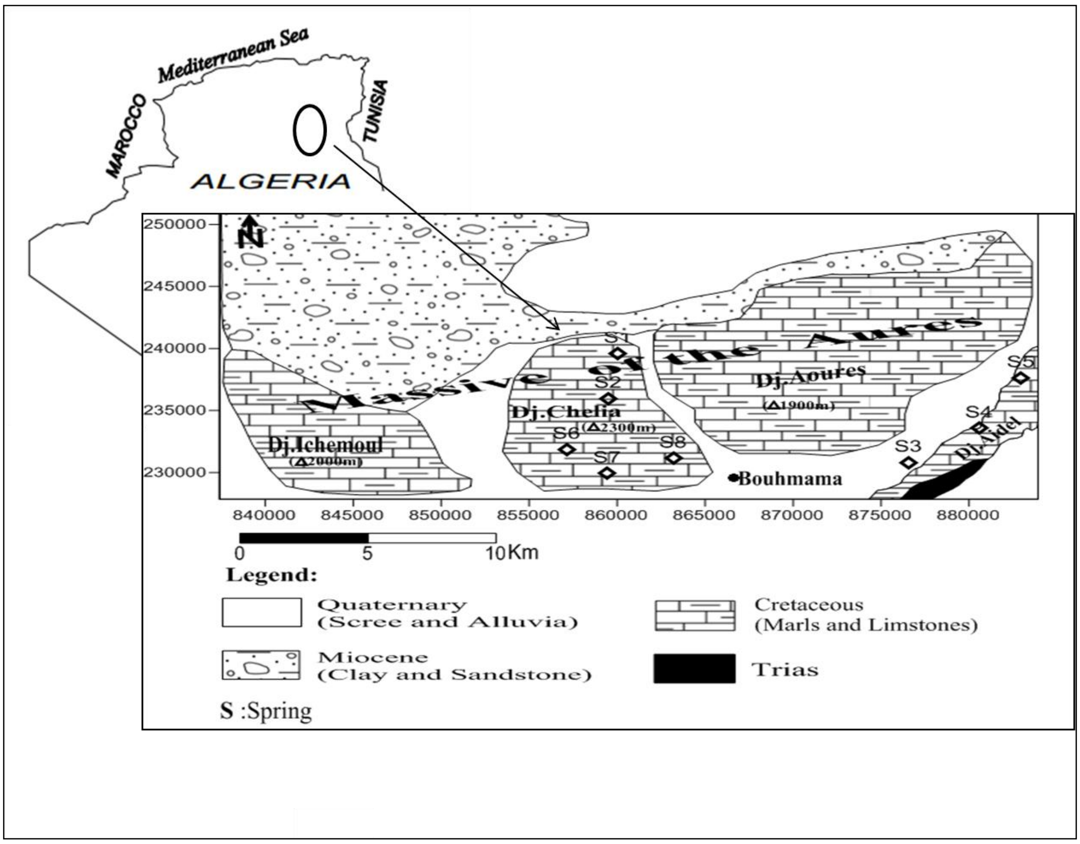

Figure 1: Location and geological features of the study area.

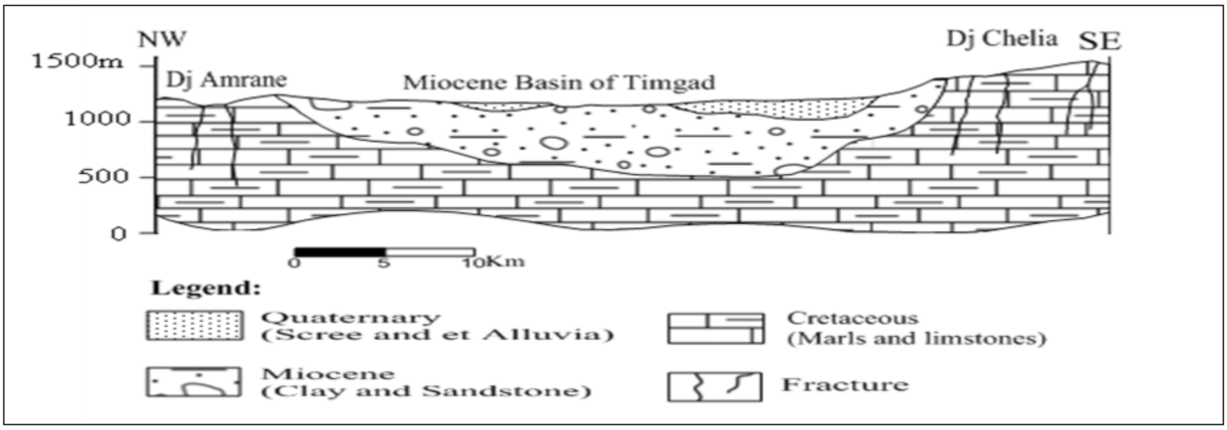

Figure 2: Geological cross section.

3. Material and Methods

A sampling of eight water springs capturing the Cretaceous aquifer (Figure 1) has been carried out during the rainy period in April 2015. The electrical conductivity, the temperature and the pH have been measured in the field. The results of the chemical analyses of major elements, the ratio of stable isotopes 2H and 18O, carried out in the laboratory of isotopic hydrology of atomic research center of Algiers (CRNA) are provided in Table 1.

Table 1: Results of physico-chemical and isotopic analyses of the of the water springs of the study area

Samples	T (°C)	EC (µs/cm)	pH	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	HCO_3^{-} (mg/l)	Cl^{-} (mg/l)	SO_4^{2-} (mg/l)	$\delta^{18}O$ ‰	$\delta^{2}H$ ‰
S1	16	491	6.9	95.4	30.3	15.4	2.6	295.9	16.5	79.9	-7.77	-48.3
S2	14	394	6.8	34.2	36.3	5.6	2.3	308.1	7.7	19.8	-8.88	-55.7
S3	14	492	6.8	91.6	25.1	11.1	1.8	320.3	17.2	50.4	-8.16	-50.2
S4	14	382	6.8	83.6	27.4	5.8	2.1	318.7	10.4	16.9	-8.72	-55.3
S5	12	675	6.67	110.9	51.4	8.5	2.8	536.8	18.4	50	-8.58	-53.4
S6	14	200	7.04	32.7	10.7	3.4	1.6	114.4	5.7	13.1	-9	-55.9
S7	14	288	7	50.4	17.1	3.9	1.7	204.4	6.5	15.5	-9.53	-60.7
S8	15	511	6.8	91.8	36.8	7.5	2.5	382.8	13.9	36.6	-9.33	-58.3

4. Results and discussion

4.1. Hydrochemistry

The water temperatures of the water springs are comprised between 12 and 16°C, with a mean value of 14°C. The groundwater pH values range from 6.67 to 7.04. The electrical conductivity varies between 200 and 675 µS.cm-1. The report of major elements contents of different sampled points of water on Piper diagram (Figure 3) shows that the cretaceous waters exhibit a bicarbonate-calcium facies because calcite is abundant in these aquifers [13, 14].

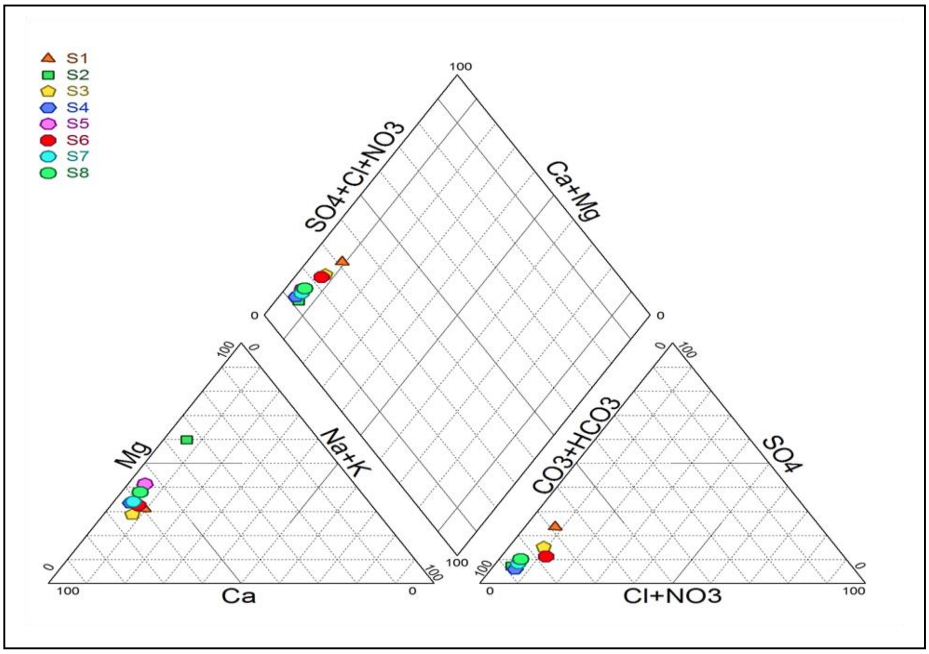

Figure 3: Piper diagram for the water samples

4.2. Mineralization acquisition

To better distinguish the salinization process of groundwater, we have employed the cross diagrams of major elements with chlore ion (Figuer 4). This latter is a conserved element, is not involved in water-rock interactions, characterizes the origin of water salinity and constitutes a mixing tracer [5]. The disposition of the different points of waters analyzed with respect to the mixing line freshwater- saltwater (rainwater- seawater) can be of great interest to identify other phenomena, which are annexed to the mixing process [15, 16]. The relationship between Na^+ and Cl^- (Figure 4) reveals that all the points are below the mixing line. Given that Na^+ content should balance the Cl^- content, the Na^+ deficit is explained by the exchange phenomenon of ionic base between water and the aquifer, and is reflected by Na^+ absorption and Ca^{2+} release. The graph Ca^{2+} versus Cl^- illustrates well this, showing that the points are often over the mixing line of freshwater- saltwater.

The relationship between Mg^{2+} and Cl^- reveals that the majority of the points are located on the mixing line with a tendency to the Mg^{2+} enrichment which might be related to the dolomite dissolution [15-18]. The graph SO_4^{2-} and Cl^- demonstrates that all the points are over the mixing line of freshwater- saltwater. The sulphate enrichment might be caused by the gypsum dissolution, the leaching of evaporites [15].

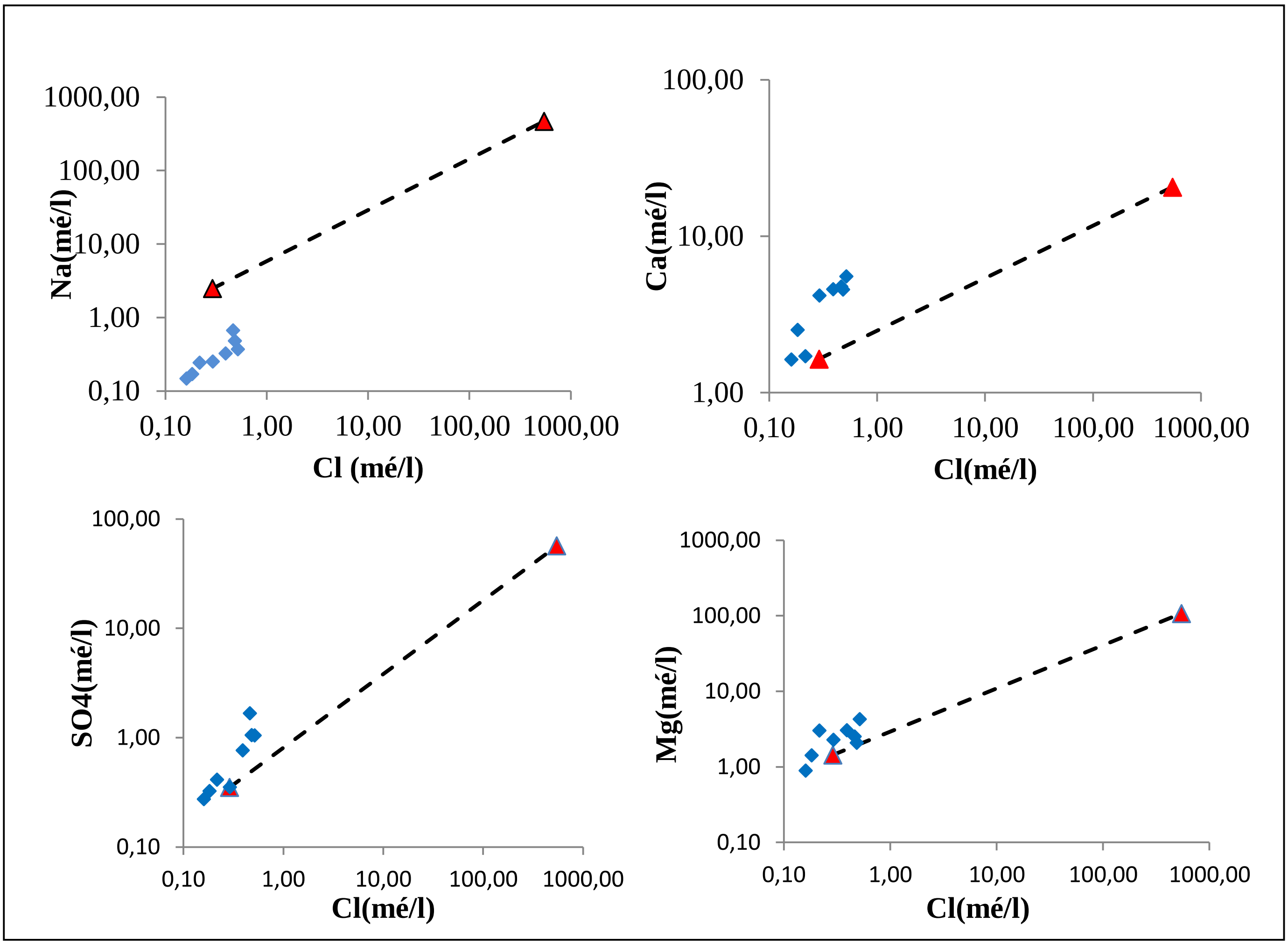

Figure 4: Relationship between major elements and chloride.

4.3. Saturation index of water samples

The study of the geochemical processes which have caused the salinization of the water springs of the Algerian upper plains and their saturation with respect to the minerals is based on the ionic activity calculation. The saturation index expresses the chemical balance degree between water and the mineral in the aquifer matrix, considered as a measure of the dissolution process and / or the precipitation regarding water-rock interaction.

The use of the geochemical programme of PHREEQ, integrated in the diagram programme of the hydrochemical calculations [19] has allowed us to calculate the saturation index of calcite, dolomite, aragonite, gypsum, anhydrite and halite. The significant results of all the analyzed water samples Table 2 show that calcite saturation index of sampled water (Figure 5) in relation to concerned minerals indicates an undersaturation state of most sampled waters, and this illustrates the close correlation between calcite saturation index and concerned ions; this correlation confirms carbonate minerals dissolution [13, 14].

Table 2: Calculated values of the saturations indexes

samples	Anhydrite	Aragonite	Calcite	Dolomite	Gypsum	Halite
S1	-1.86	-0.31	-0.16	-0,48	-1.64	-8.18
S2	-2.82	-0.79	-0.64	-0,91	-2.6	-8.94
S3	-2.06	-0.38	-0.23	-0,68	-1.84	-8.3
S4	-2.55	-0.4	-0.26	-0,65	-2.33	-8.8
S5	-2.07	-0.25	-0.1	-0,19	-1.85	-8.41
S6	-2.9	-0.93	-0.79	-1,71	-2.68	-9.26
S7	-2.71	-0.57	-0.43	-0,97	-2.49	-9.16
S8	-2.22	-0.31	-0.16	-0,37	-2	-8.57

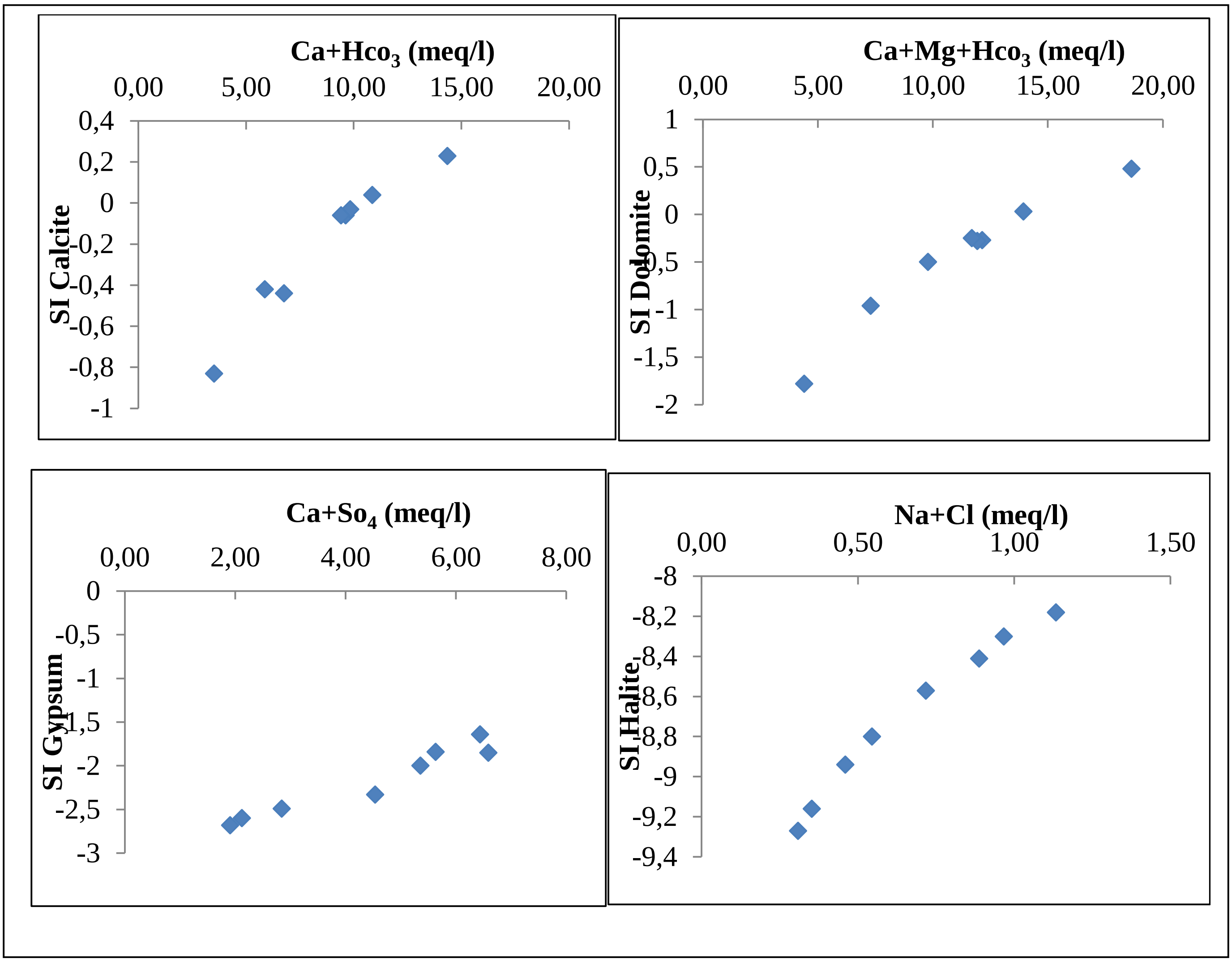

Figure 5: Plots of $(Ca^{+}+Hco_3^{-})$ versus SI of Calcite, $(Ca^{+}+SO_4^{-})$ versus SI of gypsum, $(Ca^{+}+Mg^{+}+Hco_3^{-})$ versus SI of Dolomite and $(Na^{+}+Cl^{-})$ versus SI of Halite.

Dolomite saturation index of most samples is negative (figure 5), which also confirms the dissolution hypothesis of these minerals in water. Gypsum dissolution (figure 5) is confirmed through the proportional relationship between water saturation index with respect to this mineral and the sum of ions, here of probable dissolution. Sampled water is undersaturated with respect to halite, indicating the dissolution possibility of this mineral. This probable dissolution is corroborated by the close correlation between the saturation index of this mineral and ions Na^{++} Cl^{-} (figure 5).

4.4. Isotopic hydrology

Measures of stable isotopes contents (oxygen 18 and deuterium) have been carried out on 8 water samples (Figure 1). The stable isotopes contents have been reported on diagram δ2H=f (δ18O) (Figure 6), where also appear:

- The Global Meteoric Water Line (GMWL) of equation δ 2H=8 δ18O+10 [10].
- The Western Mediterranean Meteoric Water Line (WMMWL), of equations δ^2H=8 δ18O+13.7 [21].

This graphic representation (Figure 6) shows that the water springs present an impoverished isotopic signature[22], the mean weighted δ18O value is -8.75 ‰ vs-SMOW. According to the diagram δ18O/δ2H (Figure 6), the water springs are located near the WMMWL; this indicates that the aquifer recharge of Cretaceous has been made from rainwaters of mediterranean origin in high altitudes [23, 24]. The impoverished feature of the water springs signifies that the isotopic composition of the precipitations evolves with the altitudes and becomes more and more impoverished in δ18O and δ2H when it increases (Figure 7) [26,22]. The effect of the altitudes is in good agreement with the Aures massif [15], whose relief is the most marked, and culminates at 2300 m [22, 23]. On average, the waters of these springs indicate a deuterium excess of 15 ‰, which is nearer to 13.7 ‰, which characterizes the mediterranean originated waters than 10 ‰ characterizing the oceanic originated waters [25, 26].

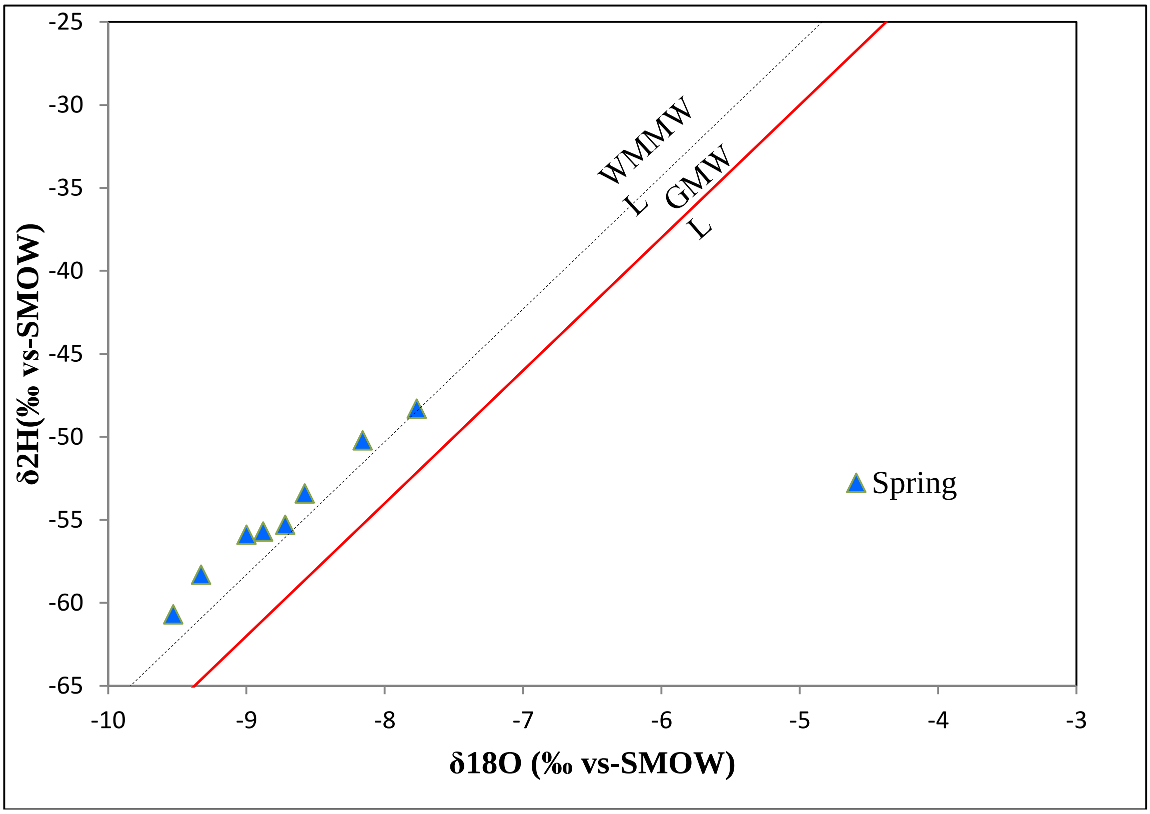

Figure 6: δ^2H vs δ^{18}O relationship for groundwater of the study area.

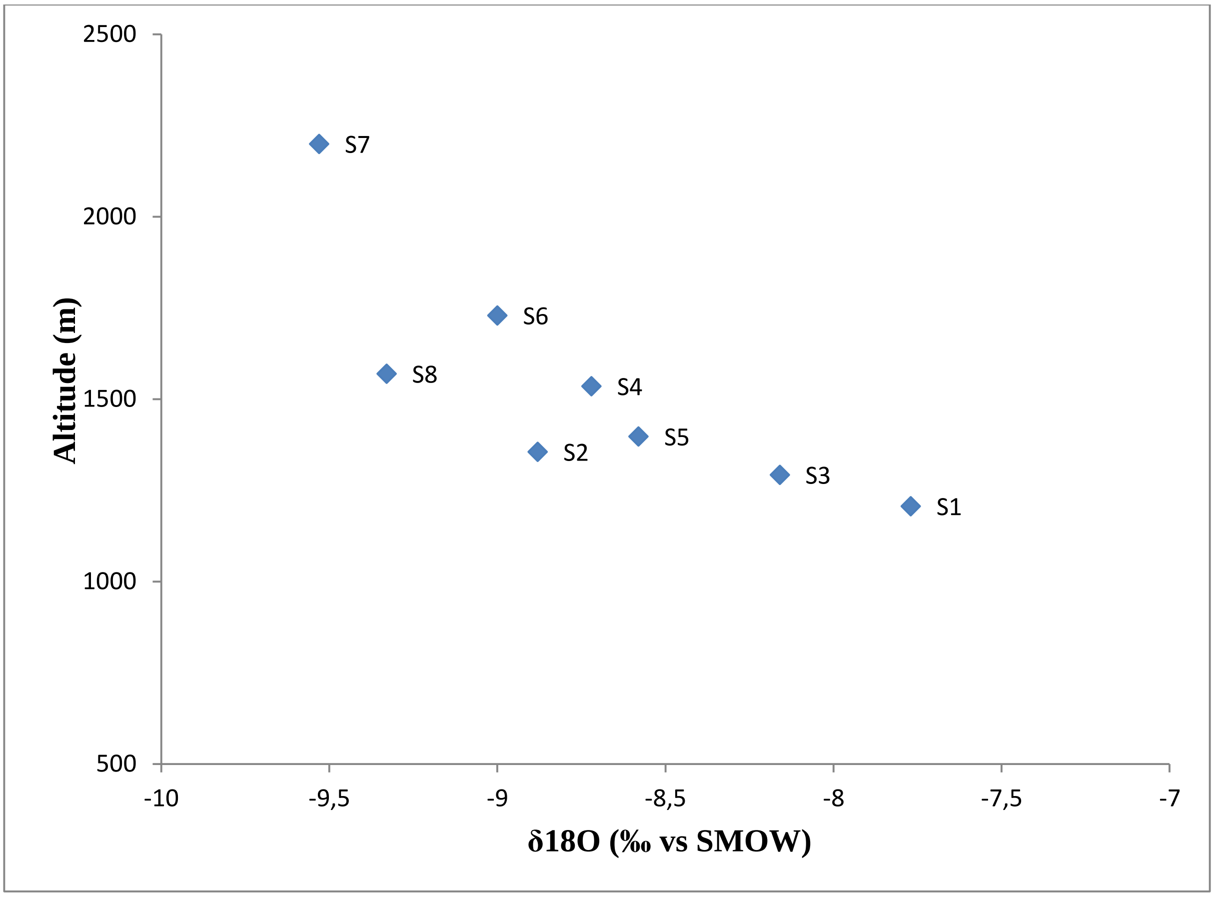

Figure 7: Altitude and δ^{18}O relationship of water samples

Conclusions

The water springs of Algerian upper plains are not yet enough mineralized, and can become salty by water-rock interaction. Water springs are of bicarbonate-calcium facies.

The use of chemical tool has shown that the origin of waters mineralization is linked to water-rock interactions by mineral dissolution and cation exchange, and shows that the water springs are undersaturated with respect to calcite, dolomite, aragonite, gypsum, anhydrite and halite. The isotopic tool utilization has shown that the origin recharge of the cretaceous aquifer is ensured by rainwaters of mediterranean origin. This is confirmed by a deuterium excess value of 15‰. The impoverished feature of the waters springs in oxygen 18 is attributed to the altitude effect.

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References

1. N. Carrard, T. Foster, and J. Willetts, Groundwater as a Source of Drinking Water in Southeast Asia and the Pacific: A Multi-Country Review of Current Reliance and Resource Concerns, *Water* 11(8) (2019) article 1605; https://doi.org/10.3390/w11081605
2. R. P. Schwarzenbach, T. Egli, T. B. Hofstetter, U. von Gunten, B. Wehrli, Global Water Pollution and Human Health, *Annu. Rev. Environ. Resour.* 35 (2010) 109–36
3. R. A. Mandour, Human health impacts of drinking water (surface and ground) pollution Dakahlyia Governorate, Egypt, *Applied Water Science*, 2 (2012) 157–163, https://doi.org/10.1007/s13201-012-0041-6

4. Peter H. Gleick, Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020, Pacific Institute Research Report, (2002), www.pacinst.org
5. A. Joshi and C. Amadi, Impact of Water, Sanitation, and Hygiene Interventions on Improving Health Outcomes among School Children, *J Environ Public Health.* 2013 (2013) article 984626. https://dx.doi.org/10.1155%2F2013%2F984626
6. F. Baali, A. Rouabhia, N. Kherici, L. Djabri, L. Bouchaou, A. Hani, Qualite des eaux souterraines et risque de pollutionen milieu semi-aride : Cas de la cuvette de Chéria (NE Algerien) [Underground water quality and contamination risk : The case of the basin of Cheria NE Algeria], *Estudios Geológicos*, 63 (2) (2007) 127-133
7. N. Tahar, B. Ali, Hydrochemistry and Assessment on Groundwater Quality of the Aquifer of Heliopolis in North of Guelma-Algeria, *International Journal of Scientific & Engineering Research*, 7(11) (2016) 318-324
8. S. Zereg, A. Boudoukha, L. Benaabidate, Impacts of natural conditions and anthropogenic activities on groundwater quality in Tebessa plain, Algeria, *Sustainable Environment Research*, 28(6) (2018) 340-349, https://doi.org/10.1016/j.serj.2018.05.003
9. R. Belhadj Aissa, D. Boutoutaou, Characterization of groundwater in arid zones (case of Ouargla basin), *Energy Procedia*, 119 (2017) 556-564
10. L. Belkhiri, L. Mouni, Geochemical modeling of groundwater in the El Eulma area, Algeria. *Desalination and Water Treatment.* 51(7–9) (2012) 1468–1476, https://doi.org/10.1080/19443994.2012.699350
11. B. Houha, Etude du fonctionnement hydrogéochimique et salin d'un bassin semi-aride. Remila, Khenchela. Doctorate thesis, university of Annaba, Algeria (2007) pp. 140.
12. Ch. Berkani, B. Houha, Hydro-geochemical Characterization of Water Springs of the Aurès region. (North-eastern Algeria), *J. Mater. Environ. Sci*, 7 (6) (2016) 1856-1865
13. M. Barbieri, A. Nigro, M. Petitta, Groundwater mixing in the discharge area of San Vittorino Plain (Central Italy): geochemical characterization and implication for drinking uses, *Environ. Earth Sci*, (2017) 76-393.
14. H. Amor, F. Baali, R. Hadji, H. Zerroki, H. Besser, N. Moukadem, R. Legrioui, Y. Hamed, Hydrogeochemical characterization of water mineralization in Tebessa‑Kasserine karst system (Tuniso‑Algerian Transboundry basin) *Euro-Mediterr. J. Environ. Integr*, (2018) 3:7, https://doi.org/10.1007/s41207-017-0045-6
15. N. Belkoum, B. Houha, Hydrochemistry and isotopic geochemistry contribution to the characterization of the aquifers of the upper Plains of Algeria, case of the basin of Chemora, oriental Algeria, *J. Mater. Environ. Sci*, 8 (9) (2017) 3262-3268
16. A. Benmoussa, A. Sedrati, N. Belkoum, B. Houha, Chemical and isotopic characterization of the thermal waters of Hammam Skhouna Algeria, *Journal of New Technology and Materials*, 8 N°2 (2018) 94- 99
17. S. Djoudi, B. Houha, The hydrochemical characterization of the upper plains aquifers: case of the plain of F'kirina Ain-Beida, Northeastern Algeria, *Desalination and Water Treatment* 92 (2017) 90–97, https://doi:10.5004/dwt.2017.21507
18. A. Sedrati, B. Houha, G. Romanescu, C. Stoleriu, Hydro-geochemical and statistical characterization of goundwater in the south of Khenchela, EL Meita Area (Northeastern Algeria), *Carpathian Journal of Earth and Environmental Sciences*, 13 (2) (2018) 333-342, https://doi.26471/cjees/2018/013/029

19. R. Smiler, laboratoire d'hydrogéologie d'Avignon (2005)
20. H. Craig , Isotopic variations in meteoric water. *Science*, 133 (1961) 1702–1703
21. H. Celle, M. Daniel, J. Mudry, B. Blavoux, Signal pluie et traçage par les isotopes stables en Méditerranée occidentale. Exemple de la région avignonnaise (Sud-Est de la France). C. R. Acad. Sci. Paris, Sciences de la Terre et des planètes, *Earth and Planetary Sciences*, 331 (2000) 647–650
22. Y. Hamed, R. Ahmadi, A. Demdoum, S. Bouri, I. Gargouri, H. Ben Dhia, S. Al-Gamal, R. Laouar, A. Choura, Use of geochemical, isotopic, and age tracer data to develop models of groundwater flow: A case study of Gafsa mining basin-SouthernTunisia, *Journal of African Earth Sciences*, 100 (2014) 418–436
23. H. Chenaker, B. Houha, V. Valles, Isotope studies and chemical investigation of hot springs from North-Eastern Algeria, *J. Mater. Environ. Sci*, 8 (12) (2017) 4253- 4263
24. F. Chelih, C. Fehdi, S. Khan, Characterization of the Hammamet basin aquifer (North-East Algeria) through geochemical and geostructural methods and analysis, *Journal of Water and Land Development*, 37 (2018) 39-48, https://doi.10.2478/jwld-2018.0023
25. D. Rochdane, V. Reddy, A. El Mandour, Hydrochemical and isotopic characterization of Eastern Haouzplain groundwater, Morocco, *Environ Earth Sci*, 73 (2015) 3487-3500, https://doi.org/10.1007/s12665-014-3633-7
26. L. Wang, G. Li, Y. Dong, D. Han, J. Zhang, Using hydrochemical and isotopic data to determine sources of recharge and groundwater evolution in an arid region: a case study in the upper–middle reaches of the Shule River basin, northwestern China, *Environ Earth Sci*, 73 (2015) 1901-1915, https://doi.org/10.1007/s12665-014-3719-2

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